4-1-1980

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TECHNICAL REPORT 96

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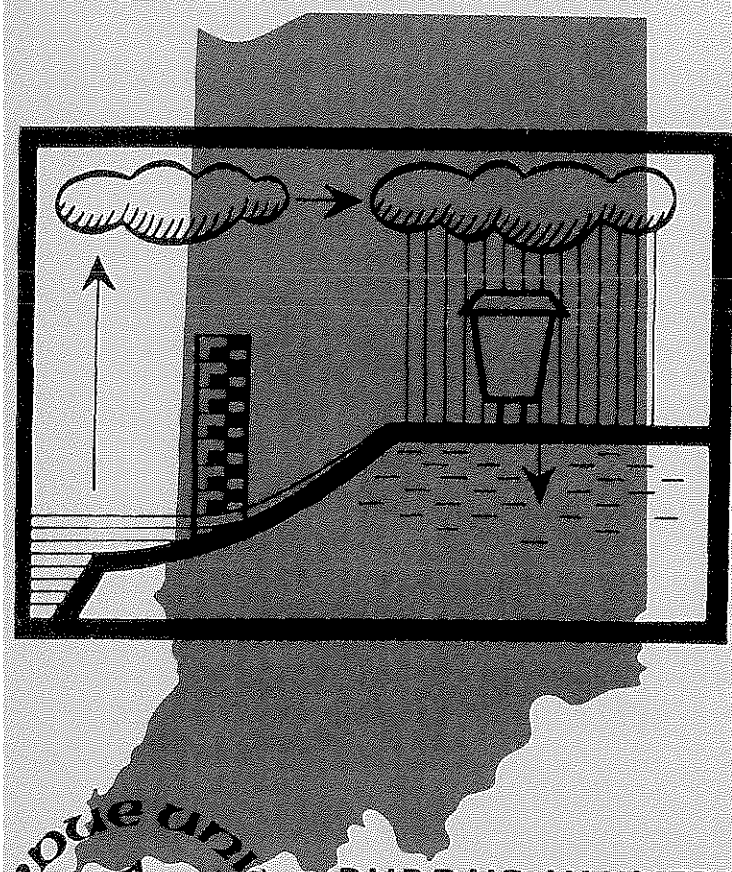

by

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April 1980

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THE ECONOMIC CONSEQUENCES OF IRRIGATING CORN ON FINE TEXTURED SOILS IN THE HUMID MIDWEST

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Purdue University Water Resources Research Center Technical Report Number 96

April 1980

This is a partial completion report contributing to project B-120-ILL entitled "Efficient Use of Water for Irrigation in the Upper Midwest." The work upon which this report is based was supported in part by funds provided by the U.S. Department of Interior, Office of Water Resources Research and Technology, as authorized by the Water Resources Act of 1964 (P.L. 88-379). The funding agreement for the project is 14-34-0001-9113.

Acknowledgments

This report covers part of the research completed under matching grant B-120-ILL funded by the United States Department of Interior through the Office of Water Resources Research and Technology. The authors appreciate the support and assistance of the members of the interdisciplinary team from the several Universities involved in this regional project, i.e.: Professors Glen Stout, Marlow Thorne and Paul Walker from the University of Illinois, Professors Vernon Eidman, Craig Sheaffer, and John Waelti from the University of Minnesota, Professors T. Al Austin, Robert Shaw, and Howard Johnson from Iowa State University. Appreciation is extended to the Directors of the Water Resources Research Center at the Universities involved in the project for their assistance in coordinating this work

The excellent review comments provided by Professors Craig Dobbins, George Patrick, Paul Robbins, and Jerry Mannering on an earlier draft of this bulletin were helpful in guiding revisions in the work. Professor Bruce McCarl provided helpful assistance in development and modification of the computer programs used in the modeling work.

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CHAPTER I

INTRODUCTION

The installation and operation of irrigation systems in the Midwest has expanded rapidly in the past decade. In Indiana, for example, the number of irrigated acres has increased from less than 40,000 acres in 1972 to approximately 70,000 acres in 1977. Increased interest in irrigation is occurring due to the variability of weather conditions and the increased financial risk associated with crop failure. Weather conditions in the Midwest during the 1970's, particularly the amount and distribution of rainfall during the year, matched much more closely the variability recorded for the 100 years of weather records than did the stable weather patterns of the 1950's and 1960's. This has increased the risk associated with the inability of the farm manager to control the moisture variable in the farm production process.

Economic risk in farming has increased for several reasons. Farm size has been increasing along with the degree of enterprise specialization. Also, risk has increased due to increases in input cost. Even though farm income has been on the rise due to higher domestic demand and increased exports, so has the value of agricultural land. The higher land prices combined with increases in other inputs, such as fertilizer and seeds, commits a farm operator to major cash outlays for crop production. With these high operating outlays financial losses may occur if drought conditions prevail. For those farmers with high debt to asset ratios, the consequences of crop loss may be financial disaster.

Substantial research has been conducted on the economic profitability of irrigation on coarse textured soils in the Midwest. Irrigation systems have been adopted on these soils due to the production response of corn to water and the low cost of well water which generally is available at shallow depths.

However, limited research attention has been focused on fine textured soils. Since these soils have high water holding capacity, irrigation has not been needed in the humid regions to supplement rainfall. However, fine textured soils with restricted zones for plant root development, such as claypan or fragipan soils will have higher crop yields when irrigation is provided during the low rainfall periods of July and August. Recent agronomic data indicates corn on a claypan soil (Hein [1980] and Thorne [1978]) responds to irrigation. The research reported here is designed to examine the economic returns in the humid Midwest of irrigating fine textured soil with a restricted root zone.

Although previous economic research is not available on the fine textured soils with restricted rooting zones, it is quite helpful to review the economic research that has been conducted on sandy soils in the Midwest during the past two decades. For discussion purposes this research can be divided into two groups. The first involves farm management investment budgets of the returns from irrigation systems, while the second group involves mathematical programming investment planning models of farm management systems which include irrigation.

Farm budgets prepared by Robbins, et al. [1977], Eidman [1978], Schwab and Kidda [1976], and Sanghi and Klepper [1976] are examples of several types of farm budgets prepared for irrigation on coarsely textured soils. The level of detail in these budgets varies from the brief analysis prepared by Schwab and Kidda for corn production to the comparison of several alternative irrigation systems by Robbins. The publication by Eidman provides the most detailed presentation and includes worksheet illustrations which can be used for the economic analysis of any system. It provides information to assess the returns from irrigation for many specialty crops as well as the major crops produced in Minnesota.

The second research approach involves use of mathematical programming models to determine the investment opportunities in irrigation. These models are usually based on farm planning models, used extensively in the Midwest, with the addition of an irrigation investment activity to the other production activities already included in the model. Examples of these models include research by Windsor and Chow [1970], which utilized both linear and dynamic programming models to compare irrigation systems and research by Schoney [1977], who analyzed irrigation opportunities in Wisconsin. Recently there has been interest in developing models which analyze water application throughout the irrigation season to develop the most profitable scheduling of irrigation applications. Work by Mapp and Eidman [1976] provides an example of this type of research.

Very limited economic irrigation research has been completed on claypan type soils. Walker and Lembke [1977], examined agronomic aspects of irrigation on claypan soils. They include a brief financial budget of the irrigation system similar to the farm management investment budgets described above. This is the only assessment known to the authors of the economics of irrigation on claypan soils that has been completed and published for Midwestern conditions.

The objectives of this research are:

1) to utilize a micro-economic farm planning model to analyze investments in irrigation technology and irrigation system operation suitable for Midwestern agricultural operations;

2) to evaluate the economic potential for irrigating corn grown on claypan soils with alternative cost discount rate, and yield assumptions;

3) to evaluate the economic potential of different sources of water for the irrigation system.

CHAPTER II

THE CLAYPAN AREAS

Crop Response to Irrigation

Soil conditions are an important factor influencing the use of irrigation systems for claypan soils. The low rates of infiltration in claypan soils make it difficult to use some of the irrigation systems which may be economically competitive for sandy soil conditions. For example, the big gun traveler systems and many center pivot systems have high application rates which make them difficult to use on claypan soils unless the soil is protected by a dense crop canopy. Since most supplementary irrigation in the Midwest occurs during July and August when the soil is protected with an extensive crop canopy, it is still possible to use this system under certain conditions. However, many claypan equipment installations involve use of the center pivot irrigation systems since the cost per acre for these systems with multiple sites is less than the other systems. (See Apland [1977] and Robbins, _et al_. [1977]) The center pivot is particularly attractive due to the low labor requirement per acre irrigated in comparison to the other irrigation systems. Alternative forms of sprinkler irrigation are the only methods considered since topography makes flood irrigation impractical for most claypan soils.

The unique character of the claypan soil with its restricted rooting zone influences the frequency of irrigation, as well as the amount of irrigation water applied per irrigation. The more limited the area for root growth between the soil surface and the impermeable layer, the more frequently irrigation water will need to be applied and the less water which will be required per irrigation.

Claypan soils are located in many areas of the Midwest. The Vigo soils in Indiana, the Cisine soils in Illinois and the Mexico soils in Missouri are examples of claypan soils with several common characteristics. These soils usually have from eight inches to 23 inches of topsoil which cover a tight clay subsoil. The poorly drained Vigo soil has a light colored silt loam A horizon, a silty clay B horizon and a buried clayey B horizon. Since the Vigo soil may have as deep as a 23 inch siltloam A horizon it is a somewhat better soil than either the Cisine or Mexico. The gently sloping Cisine soil has eight to 10 inch deep silt loam surface soil underlain by a heavy silty clay loam subsoil. The Mexico soil has about 12 inches of silt loam topsoil over a 12 to 18 inch clay pan layer. These soils have slop surface drainage, slow permeability and poor resistance to drought because of the restricted root zone. Although other soils with claypans or fragipans are found in these three states, these three are similar enough to provide a basis for comparison of farming conditions and crop yield response to irrigation.

Data about the response of corn to irrigation on claypan soils are available from a few sources. The Agronomy Department at the University of Illinois has conducted tests on the Cisine soils at the Brownstown Experiment Station since 1976. The results of these tests are presented in Table 2.1. Although the 1976 and 1977 data indicated yield increases of 100 bushels per acre from using irrigation, discussions with agronomists establishing the plots suggested the results were confounded by inadequate drainage on the non-irrigated plots and that a more accurate expected increase would be about 50 bushels per acre. The 1976 and 1977 increases were not expected to be obtained in later years due to better control on the plots of the drainage systems and a releveling of the plots in 1978. The 50 bushel per acre increase is more consistent with the difference in yield experienced at Brownstown between irrigated plots in the test and non-irrigated corn raised on the experimental farm but not part of the irrigation tests.

Table 2.1. The Response of Corn to Irrigation, Brownstown, Illinois.[a/]

Treatment	Year 1976 (Bu./A.)	1977 (Bu./A.)	1979 (Bu./A.)
Furrow Irrigation	152	145	176
Sprinkler Irrigation	139	150	144
No Irrigation	36	53	112

[a/] Drablos [1978 and 1979].

The test results for 1979 reflect more closely the yield response Illinois agronomists expect for the claypan soils. In this case, 1979, the average yield of 160 bushels per acre for the two irrigation experiments is 48 bushels per acre more than the 112 bushels yield of dryland corn.

The response of crops to irrigation is highly dependent upon the rainfall in July and August in the Midwest. Since the Illinois data are currently only available for three years, additional data for a longer time period were obtained on the Mexico claypan soil located in Missouri. A survey of dryland and irrigated corn yields obtained by farmers has been conducted by an Area Farm Management Specialist (Dale Schnarre) in Audrain and Callaway Counties of Missorui for the past eight years. These data are presented in Table 2.2.

Table 2.2. Corn Yields of Irrigators Surveyed in Audrain and Callaway Counties.[a]

Year	Irrigated Corn	Dryland Corn	Difference
1972	126	44	82
1973	142	98	44
1974	112	52	60
1975	118	58	60
1976	113	45	68
1977	129	94	35
1978	135	104	31
1979	145	72	73
Average	128	71	57

[a] Hein [1980].

Of particular interest in these data is the wide range in yield increases due to irrigation over the eight year period. Yield increases range from a high of 82 bushels per acre in 1972 to a low of 31 bushels per acre in 1978. Agronomists indicated that in 1979 extremely low rainfall conditions contributed to the 73 bushels per acre increase for irrigation.

Farming Systems

Several counties were selected in Indiana, Illinois, and Missouri to identify farm sizes and crop production typical for these similar claypan soils. The counties selected in Indiana that had a large proportion of the land with a Vigo soil type were Clay, Owen, Vigo, and Putnam. A similar claypan area is located in the southern section of Illinois and includes the counties of Williamson, Saline, Jackson, Franklin, Perry, Randolph, Jefferson, Hamilton, White, Wayne, Marion, Edwards, Lawrence, Richland, Clay, and

Crawford. In Missouri the counties examined were Audrain and Callaway.

The size of farms located in selected claypan areas of Illinois, Indiana, and Missouri are described in Table 2.3. These data indicate that the largest number of farms is in the 50 to 179 acre group. The next largest number of farms is in the 180 to 499 acre size range. The distribution of farm size suggests that it may be appropriate to examine irrigation systems for the farm range of 50-179 acres, since they represent the largest single class of farms. However, over three times as many total acres are farmed in the 180 acre to 999 acre classes than in the 50 to 179 acre class. To represent farms with the largest acreage would suggest modeling larger farm sizes.

Adding to the complexity of representing a "typical" farm situation is the recent study of irrigation operations in Indiana. (State of Indiana [1979]). This study indicates most farms irrigated in the state are in the large size class of 500-999 acres. This is not totally unexpected since larger operations have a tendency to innovate before some of the smaller farming operations and they have greater loan repayment capacity which gives them access to the capital needed to purchase irrigation systems. Therefore, investment in irrigation systems in this study will be examined on a 640 acre farming unit.

The two major crops produced in Indiana, Illinois, and Missouri are corn and soybeans. In 1974 the acreage of corn slightly exceeded the acreage of soybeans harvested in these states. More recently, due to relative price changes between soybeans and corn, the acreage of these crops are almost identical. These two crops account for over 90 percent of all land harvested in these states. Similar to the crop acreage throughout the states, corn represents the largest crop produced in the claypan area.

Table 2.3. Characteristics of Agricultural Operations in Selected Claypan Areas of Indiana, Illinois, and Missouri, 1974.[a]

Characteristic	Indiana[b]	Illinois[c]	Missouri[d]
Number of Farms by Size			
All Farms	3,507	19,035	2,793
10-49 Acres	811	3,069	288
50-179 Acres	1,405	7,176	1,012
180-499 Acres	880	6,311	993
500-999 Acres	247	1,536	342
Over 1,000	57	274	82
Corn Harvested for Grain			
Acres	145,695	553,991	77,744
Average Bu. per Acre	65	62	54
County Range in Yield	58-71	52-69	53-54
Soybeans Harvested			
Acres	142,278	1,113,341	163,250
Average Bu. per Acre	22	21	23
County Range in Yield	20-22	18-24	23

a/ U.S. Bureau of Census [1974].

b/ The claypan area of Indiana considered is the following four counties: Clay, Owen, Putnam, and Vigo.

c/ The claypan area of Illinois selected for inclusion is the following 16 counties: Bond, Clay, Clinton, Edwards, Effingham, Fayette, Franklin, Hamilton, Marion, Perry, Randolph, Richland, Saline, Washington, Wayne, and Williamson.

d/ The claypan area of Missouri selected for consideration involves Audrain and Callaway Counties.

In 1974 777,430 acres of corn were harvested in these counties. The largest acreage was harvested in Audrain County, Missouri (33,472) and the highest yield was obtained in Saline and Washington Counties, Illinois (74 bushels/acre). A total of 1,418,869 acres of soybeans were harvested in the counties selected to represent similar claypan soil types in these three states.

The most acres of soybeans in the claypan region were grown in Audrain County, Missouri (125,624 acres). The highest yield, an average of 24 bushels per acre in 1974, was produced in Edwards County, Illinois. Since corn and soybeans are the major commercial crops produced in these regions, farm planning models developed to assess irrigation profitability should include both of these crop enterprises.

CHAPTER III

THE MODEL

A mathematical programming model of a micro farm unit, producing grain is used in this study. The model used is similar to Purdue University's B-9 Farm Management model. (See McCarl [1975]) The model maximizes net farm revenues by choosing production levels, subject to technical constraints between inputs and outputs, and an initial endowment of fixed resources. In addition to the basic model formulation, an investment model of alternative irrigation systems developed by Apland [1977] is incorporated.

The complete model is:

$$\text{Maximize } C_1' X_1 + C_2' X_2$$

$$\text{subject to } A_1X_1 + A_2X_2 \leq b$$

$$X_1, X_2 \geq 0$$

$$X_1 \text{ integer}$$

where:

C_1 is an $n_1 \times 1$ vector of investment cost,

C_2 is an $n_2 \times 1$ vector of net revenues,

A_1 is an $M \times N_1$ matrix of technical coefficients for the alternative investment decisions,

A_2 is an $M \times N_2$ matrix of technical coefficients for production activities,

X_1 is an $n_1 \times 1$ vector of discrete investment activities, and

X_2 is an $n_2 \times 1$ vector of production activities.

The model considers six alternative grain production activities for a 640 acre farm in Southwestern Indiana. Crops included in the model are dryland corn, four alternative acreage levels of irrigated corn, and soybeans. The estimated market price for corn is $2.39 per bushel and $5.74 per bushel for soybeans. Field time and labor time during the growing season are accounted for in the model, to capture the effects of various planting and harvesting dates on crop yields. Activities included for each crop are land preparation, planting, harvesting, hoeing, cultivating, labor employment, and marketing. Irrigation application of six inches of water during July and August is an activity considered for the irrigated cropland. The model is constrained by tractor availability, harvest time, good field time, labor, and land.

Since the mathematical programming model is an annual model, the results from it were used as input into a multiperiod decision model which assessed the net present value of the annual cash flow after taxes for each alternative cropping system studied. The returns to fixed investment, labor, and management determined by the animal model provided the data needed to calculate the net present value of the annual cash flow after taxes for a 15 year period. Fifteen years was selected because it appeared to be a reasonable estimate of the life of an irrigation system. It should be noted that there is no _a priori_ reason to believe that the alternative crop management system which generates the maximum net returns to fixed cost in the mathematical programming model will produce the greatest net present value of the annual cash flow after taxes.

Previous research by Apland evaluated Big Guns and Center Pivots as alternative irrigation systems. Apland's research concluded that center pivot systems are the most economical, so only those systems are included as irrigation investment alternatives in this model. This is consistent with current relative prices because most of the new systems being adopted by farmers in the Midwest are center pivots. The model was constrained to introduce irrigated systems only in blocks of 160 acres. Consequently, zero, 160, 320, 480, and 640 were the acreages that might appear in model solutions for irrigated corn production on the 640 acre farm.

Although only one type of irrigation water distribution system was modeled, three types of water sources were explored in the investment model. Wells represented the first alternative; the cost included in the investment decision are drilling, pipes, and pump cost. The second alternative was storage ponds which involves the cost of excavating the pond area. The final alternative considered for water storage was pond development through dam construction. This alternative is feasible in the claypan area due to the numerous ravines and gulleys associated with this topography. Note that the second and third alternatives are not distinctly different but involve primarily different ratios of water impounded to earth excavated during construction.

Data used for the model were collected from several sources. The majority of the data were obtained from farm records kept by Purdue University. All major assumptions of Purdue's B-9 model were retained and for the reader concerned with these assumptions it is suggested they read McCarl [1975]. Other sources of economic data were the publication of Robbins et al. [1977] and Apland [1977]. Claypan crop response data were obtained from the crop plots maintained at Brownstown, Illinois by the University of Illinois. (Drablos et al. [1979]) The Brownstown data were from actual claypan crop plots where comparisons were made between irrigated and non-irrigated corn. Additional crop response data were obtained from farm surveys of irrigated and non-irrigated corn production on claypan soils in Missouri. (See Hein [1980])

CHAPTER IV

ANALYSIS

The economic potential for irrigation on clay soils with restricted rooting zones is explored in this chapter. The first section evaluates dryland corn and soybean production as a basis for comparison with the irrigated system. The next section introduces weather variability into dryland corn production by evaluating dry weather in the early and late years of the 15 year period used for investment evaluation. The next section examines irrigated systems of corn production supplied from well water sources at three levels of cost of the irrigation system. Then, surface water impoundment as a source of water is evaluated for corn production at two levels of cost and at four levels of irrigated acreage on the 640 acre case farm. The final section of this chapter considers the profitability of irrigation for three alternative levels of crop yields and three levels of discount rates. Of particular interest throughout the analysis is the comparative profitability between dryland and irrigated systems of corn production when system cost, water source, yield, and rate of discount are altered.

In order to compare the profitability of the potential alternative irrigation system designs for the claypan area, the discounted present value of the net cash flow was calculated over the 15 year expected life of the irrigation investment. These comparisons indicate the true measure of investment profitability for after tax cash flow and illustrate how income taxes influence profitability. For more details on the composition and calculation of cash flows see Dobbins [1979].

The amount of taxes paid are influenced by the way depreciation, investment credit, and loss carryover are utilized as well as by the revenue and costs directly associated with the investment. In this study depreciation,investment credit, and loss carryover were utilized in the way which would maximize the after tax cash flow for each production system. An example of the detailed calculation of after tax cash flow for one system is presented in Appendix A. The basic principle involves insuring the farm operator takes advantage of each tax reducing technique to its fullest by selecting the best depreciation schedule to complement investment credit and/or loss carryover. The simple approach of using the most rapid depreciation schedule consistent with the expected life of the investment is not always the approach which maximizes the present value of the net cash flow after taxes. For example, loss carryover and investment credit may reduce income taxes to zero in the first few years of the project so a straight line depreciation schedule results in the greatest net present value of cash flow after taxes.

In order to standardize the comparison across irrigation systems, a four person family with no income outside the farm was assumed. Further, it was assumed that in year one there was no carryover of investment creidt or losses from previous years.

Dryland Production

The first cropping program examined was for dryland soybeans to be grown continuously on the entire farm. Soybean yields were assumed to be a maximum of 30 bushels per acre if planted and harvested at the agronomically optimum time. Yields as low as 24 bushels per acre were harvested from some of the land which was planted and harvested at the least opportune time consistent with labor, machinery, and weather constraints. No penalty in yield was assessed for continuous production of the same crop. The economic consequences of this cropping pattern is presented in Table 4.1.

Table 4.1. Economic Returns to Dryland Production of Corn and Soybeans.[a]

System Profile	Dryland Soybeans	Dryland Corn	Soybean/Corn Rotation
Acreage	640 A. Soybeans	640 A. Corn	320 A. Corn 320 A. Soybeans
Revenue	106,079	146,353	129,014
Allocated Variable Cost	26,726	39,750	33,238
Return to Fixed Cost, Labor and Management	79,353	106,353	95,776
	--------Annual Net Cash Flow After Taxes--------		
Year 1	6,073	30,374	22,029
2	6,073	30,374	22,029
3	6,073	30,374	22,029
4	6,073	30,374	22,029
5	6,073	30,374	22,029
6	6,073	30,374	22,029
7	6,073	30,374	22,029
8	6,073	30,374	22,029
9	6,073	30,374	22,029
10	6,073	30,374	22,029
11	6,073	30,374	22,029
12	6,073	30,374	22,029
13	6,073	30,374	22,029
14	6,073	30,374	22,029
15	6,073	30,374	22,029
Present Value of Annual Net Cash Flow	51,982	259,986	188,557

[a] The cash flow after taxes was calculated by subtracting fixed annual costs of capital, labor, land and property taxes from the returns to the fixed cos cost, labor, and management calculated in the annual mathematical programming model. A fixed farm machinery loan payment of $23,040, a land rental cost of $42,240 and a hired labor cost of $8,000 were assessed to each system.

The gross receipts were $106,079 with $26,726 expended for allocated variable costs. The return to fixed investment, labor, and management was $79,353. When the fixed costs and taxes were assessed net annual cash flow available to the farmer for his labor and management was $6,073. The present value of this annual net cash flow at an eight percent discount rate would be $51,982 for the 15 year period.

In contrast, the dryland corn production generated $146,353 in gross revenues. When the allocated variable costs were subtracted from gross revenue $106,353 remained as returns to fixed investment, labor, and management. The annual net cash flow after taxes for corn amounted to $30,374. When this is discounted to present value at an eight percent rate of discount, it yields $259,986 over a 15 year period.

The dryland corn program has a base yield of 101 bushels per acre when planted and harvested at the optimum time. Since the 640 acre farm has limited labor and machinery, the average yield is never as great as the base yield for any management system. Table 4.2 presents the acreage and yield per acre for dryland corn production by each planting and harvesting period. The actual average yield per bushel for all acreage planted and harvested in different periods in this production system was 96 bushels (in contrast to the 101 bushels base yield).

The third dryland cropping program examined to provide a comparison to the irrigation systems is a combination system where the farmer plants one-half of the land to corn and one-half to soybeans each year. This system is the most realistic of the three dryland systems because it permits more effective use of labor and machinery during the cropping years. In addition, it is preferable to assume no yield penalty over time when a crop rotation can be practiced by the farmer. This third system is not

Table 4.2. Acres and Yield of Dryland Corn Planted and Harvested by Period.

Planting Period	Harvesting Period: Sept. 23 to Oct. 6	Oct. 7 to Oct. 20	Oct. 21 to Nov. 3	Nov. 4 to Nov. 26	Total Acres Planted
Apr 29-May 5	154	0	0	0	154
May 6-May 12	31	137	0	0	169
May 13-May 19	0	48	40	96	184
May 20-May 26	0	0	88	0	88
May 27-June 2	0	0	46	0	46
June 3-June 9	0	0	0	0	0
Total Acres Harvested	185	185	174	96	640
Ave. Yield per Acre	101	97	90	91	96

as profitable as continuous corn, however, due to the relative price and yield ratios assumed for this analysis. Dryland corn had a maximum base yield of 101 bushels per acre and a price of $2.39. Soybeans had a maximum base yield of 30 bushels per acre and a price of $5.74. These crop prices are used for all systems evaluated in this study.

The economic results of the corn and soybean crop combination system were gross receipts of $129,014, allocated variable costs of $33,238, and a return to fixed cost, labor and management of $95,776. This system had a present value of the annual net cash flow of $188,557. Although improvements in the timeliness of machinery and labor use occurred under this system, these cost advantages were more than compensated for by the lower revenue associated with the soybeans relative to corn production.

In order to more accurately compare dryland and irrigated systems, the wide range in yields between years indicated by agronomic data needs to be introduced into the dryland corn model. A lower base yield for dryland production (53 bushels per acre rather than 101 bushels per acre) was introduced in one year out of five years to represent poor weather conditions for those years. This lowers the average yield presented in Table 4.2 from 96 bushels per acre to 86 bushels per acre for dryland production over the 15 year period of analysis. This average yield is 45 bushels less than the average yield of irrigated corn used in this study and described later.

There are many possible sequences of years in which the lower base yield could occur. If the lower base yield was introduced in the first three years of the 15 year period, the greatest reduction would occur in the discounted net present value of the stream of annual cash flows. Two sequences of lower base yields are presented in Table 4.3. In the first sequence it is assumed that lower yields occur later in the period during years 5, 10, and 15. In the second sequence it is assumed that lower yields occur earlier in the period during years 1, 6, and 11.

Although tax reductions occur from loss carryover after the low yield years, the substantial losses that occur in those three years more than compensate for the tax gain. The present value of the annual cash flow after taxes for the late dry years is $171,672 and for the early dry years is $143,619. The average of these two structures, $157,645, is used as the basis for comparison with the irrigated systems discussed in the following sections.

Table 4.3. Dryland Corn Production with Variable Weather Conditions.[a/]

System Description	Dryland Corn with Variable Weather Conditions	
Acreage Allocation	640 Acres Dryland Corn	
	Good Weather Conditions	Poor Weather Conditions
Annual Revenue	$146,353	$76,615
Allocated Variable Cost	39,750	39,750
Return to Fixed Cost	106,353	36,854
	---The Annual Cash Flow after Taxes-----	
	Late Dry Years	Early Dry Years
Year 1	$30,374	-36,415
2	30,374	33,073
3	30,374	33,073
4	30,374	33,073
5	-36,415	32,019
6	33,073	-36,415
7	33,073	33,073
8	33,073	33,073
9	32,019	33,073
10	-36,415	32,019
11	33,073	-36,415
12	33,073	33,073
13	33,073	33,073
14	32,019	33,073
15	-36,415	33,019
PVACFAT	171,672	157,645

[a/] The cash flow after taxes was calculated by subtracting fixed annual costs of capital, labor, land and property taxes from the returns to fixed cost, labor, and management calculated in the annual mathematical programming model. A fixed farm machinery loan payment of $23,040, land rental cost of $42,240, and a hired labor cost of $8,000 were assessed to each system.

Irrigation with Groundwater

The shallow well system (100 ft. deep) considered in this section would be atypical for the claypan area in general, because poor groundwater supplies are a characteristic of this region. However, it is possible to use wells for water supplies on some farms in the region so they are briefly presented here prior to a more extensive discussion of the pond water systems.

The base yield for irrigated corn on the claypan soils is 150 bushels per acre in contrast to the 101 bushels per acre expected under dryland conditions. Yields ranged from 150 bushels per acre under optimum timeliness to 106 bushels per acre under the least timely situation encountered for this farm. The actual average yield per acre was 131 bushels under this management program. The yields and acreage by planting and harvesting periods is presented in Table 4.4.

Table 4.4. Acreage and Yield of Irrigated Corn by Planting and Harvesting Period: All acres irrigated.

Planting Date	Harvesting Period				Total Acres Planted
	Sept. 23 to Oct. 6	Oct. 7 to Oct. 20	Oct. 21 to Nov. 3	Nov. 4 to Nov. 26	
Apr 29-May 5	15	142	0	0	157
May 6-May 12	20	0	135	0	155
May 13-May 19	107	0	0	0	107
May 20-May 26	0	0	0	92	92
May 27-June 2	0	0	3	49	52
June 3-June 9	0	0	0	55	55
Total Acres Harvested	142	142	138	197	619
Ave. Yield per Acre	135	140	136	118	131

When the opportunity to irrigate corn is introduced into the cropping pattern, it is possible to compare the profitability of dryland and irrigated production. Table 4.5 presents an agronomic comparison of irrigation system cost. The medium cost system represents the cost levels typical for center pivot irrigation systems. The other systems indicate the changes that could be anticipated in net cash flow if the cost of irrigation equipment and wells was reduced 27 percent (low cost) or increased 10 percent (high cost). The lack of symmetry results from further increases in cost shifting the optimal cropping pattern from all irrigated corn to a mix of irrigated and dryland corn production. That aspect of the study will be explored in the section on impounded water.

Since cost changes in Table 4.5 occur in the fixed cost account only, the revenue is the same for each cost level of $194,180. Similarly allocated variable cost is identical for each system at $54,299. The difference between revenue and variable cost is $139,881. The similarity ends when the annual net cash flow is examined for the 15 year life of the irrigation investment. Since the cost of the irrigation investment differs for the low, medium, and high cost systems, the net cash flow after taxes is greatest for the low cost system and lowest for the high cost system. Annual cash flow in year one is $47,324 for the low cost system, $40,048 for the medium cost system and $37,278 for the high cost system. As investment credit writeoffs, interest payments on the loan, and depreciation decline over the 15 year period the after tax income falls from $40,048 for the medium cost system in year one to $28,899 in year 15.

Most interest from an economic decision criteria focuses on the present value of the annual net cash flow over the life of the investment. When discounted to present value at eight percent, the medium cost system

Table 4.5. Economic Returns to Irrigated Corn Production for Alternative Irrigation Equipment Capital Costs: Well Water Source.[a/]

System Profile	Irrigated Corn Low Cost	Irrigated Corn Medium Cost	Irrigated Corn High Cost
Acreage Allocation	619 A. corn 21 A. Lanes	619 A. corn 21 A. Lanes	619 A. corn 21 A. Lanes
Revenue	$194,180	$194,180	$194,180
Allocated Variable Cost	54,299	54,299	54,299
Return to Fixed Cost Labor and Management	$139,881	$139,881	$139,881
	------Annual Net Cash Flow after Taxes------		
Year 1	47,324	40,048	37,278
2	47,324	40,048	37,278
3	47,324	40,048	37,278
4	44,997	40,048	37,278
5	40,863	40,048	37,278
6	40,258	40,048	37,278
7	39,634	39,869	37,278
8	39,068	34,559	32,590
9	38,497	33,803	31,838
10	37,739	33,079	31,033
11	37,177	32,319	30,251
12	36,595	31,557	29,432
13	35,999	30,582	28,577
14	35,395	29,773	27,515
15	34,751	28,899	26,588
Present Value of Annual Net Cash Flow	355,903	315,293	294,909

[a/] The cash flow after taxes was calculated by subtracting fixed annual cost of irrigation equipment, capital, labor, land, and property taxes from the returns to the fixed cost, labor, and management calculated in the annual mathematical programming model. A fixed farm machinery loan payment of $23,040, a land rental cost of $42,240 and a hired labor cost of $8,000 were assessed to each system. An annual cost for irrigation systems based on loan repayment, repairs, property tax, and insurance was charged at a level consistent with the acreage of irrigation selected for a particular management system.

has a present value of $315,293. This is more profitable than either dryland corn or dryland soybeans. Under current cost conditions a farmer could increase his returns by shifting to irrigation on claypan soils when ground water is available. Even with a 10 percent increase in the system cost over current rates, irrigation still has a net present value which exceeds that of dryland production. In this case the dryland system yields a net present cash flow after taxes of $157,634 but the high cost of irrigated corn is still more profitable with a $294,909 cash flow. This indicates the irrigated system is still the more profitable system even with modest changes in cost.

Irrigation with Ponds

Ground water availability for irrigation use is extremely limited in the counties that have claypan soils. This results in the need for some type of small reservoir for storage of irrigation water. Pond water supplies have been developed in claypan regions in the past. Table 4.6 presents the number and acreage of ponds in selected claypan counties of Indiana, Illinois, and Missouri. The 22 counties in these states have an average of 551 ponds in each county and each pond is approximately three-fourths of an acre in size. If each pond has an average depth of four feet, currently 48,500 acre feed of water are stored in these counties. This suggests that soil types and topographic conditions are suitable for pond water storage and some stored water may already be available for irrigation use.

The storage of water for irrigation can be in an earthen impoundment with a wide range of ratios of cubic feet of earth moved to cubic feet of water stored. The differences depend largely on topography, soil

Table 4.6. Pits, Ponds, Reservoirs and Earthen Tanks in Selected Claypan Counties of Indiana, Illinois, and Missouri, 1974.

Item	Indiana	Illinois	Missouri
Number of Farms with Ponds	640	5132	726
Number of Ponds	1453	11801	2825
Acres in Ponds	1210	8959	2056
Average Acres per County	302	553	1028
Average Acres per Pond	.83	.75	.72

U.S. Bureau of the Census [1974].

type and type of water storage facility. When a dug pond is constructed on relatively level terrain, a ratio as high as one to one might occur. If the pond was filled by pump storage rather than runoff, 1:5 ratios might be possible depending upon the depth of excavation vs. the height of dikes around the pond. If runoff is used to recharge the pond rather than pump storage, ratios of 1:5 might still be possible if the topography of the area is undulating enough to permit dam construction in ravines. Two alternatives were considered for this analysis to illustrate the range of potential excavation to storage ratios. A pit pond dug on relatively level land but recharged by runoff with a 1 to 1 excavation to storage ratio was examined as one type of water storage. An impounded water storage facility recharged by runoff but constructed in a ravine or steeply sloping land with a 1:3 storage ratio was the other type of storage facility examined.

It is important to take advantage of the topography when designing the pond. The most desirable location would trap runoff from the watershed which could add to irrigation water from thunderstorms since the infiltration capacity of the claypan soil is very low. Drainage ditches or tubing from the fields might be directed to the storage reservoir to provide additional water for irrigation. Finally, when feasible small low volume wells could be added to provide supplemental water for the reservoir. Wells pumping at rates as low as 25 gallons per minute can provide up to nine acre inches of water per week to supplement storage from Spring rains and refills from Summer runoff.

Considerable emphasis is placed upon the siting and supplementing of reservoir water storage because the cost of storage is a major factor influencing the profitability of irrigation on claypan soils where the ground water is limited in supply. Since evaporation and seepage losses of reservoirs contribute to the need for large storage capacity, activities to reduce these losses may reduce reservoir costs by permitting smaller reservoirs to be constructed. Lining the reservoir with impermeable clay materials from the site can reduce seepage. Asphalt or plastic linings have been used under some limited conditions. The use of chemicals on the water surface has been successful in providing a modest reduction in water evaporation rates under low wind conditions.

The most effective feature to reduce evaporation losses has been the minimization of the ratio of the surface area to storage capacity of the pond within the economic costs of construction. While a deeper pond has less evaporation loss, the cost of construction is higher for it. Clearly, all of the alternatives described above have to be compared with the alternative cost of simply building a larger reservoir.

The analysis indicates the higher cost of construction for surface impoundments results in irrigated corn being a slightly less profitable investment opportunity than when shallow wells are available to supply water. However, irrigated corn with a pond water supply is still more profitable than dryland corn production under medium cost conditions when all tillable acres are irrigated. Table 4.7 indicates the medium cost system has a present value of the net cash flow after taxes of $249,658. This is greater than the present value of the net cash flow for the dryland corn which was $157,645. This comparison is not sensitive to the small change in the cost of water impoundment.

Even if the cost of surface impoundment systems could be reduced by 20 percent to yield a discounted net cash flow of $304,097 (Table 4.7), the typical shallow well supplied system medium cost would be the preferable investment at a present value of $315,293. This clearly indicates that the farm operator should explore every opportunity for a shallow well source of water supply before considering development of a surface impoundment.

Optimum Irrigated Acreage

Although irrigated corn production results in a greater discounted net present value of cash flow after taxes than dryland production, irrigation of all available land area may not be the most profitable alternative. Acreage combinations between dryland and irrigated corn was examined in order to determine the most profitable crop system. The profitability of 25 percent of the land irrigated, 50 percent irrigated and 75 percent irrigated

Table 4.7. Economic Returns to Irrigated Corn Production: Surface Water Impoundments.[a]

System Description	Irrigated Corn Low Cost	Irrigated Corn Medium Cost
Acreage Allocation	619 A. Corn 21 A. Lanes	619 A. Corn 21 A. Lanes
Revenue	$194,180	$194,180
Allocated Variable Cost	54,299	54,299
Return to Fixed Cost, Labor and Management	139,881	139,881
	Annual Net Cash Flow after Taxes	
Year 1	38,225	31,131
2	38,225	31,131
3	38,225	31,131
4	38,225	31,131
5	38,225	31,131
6	38,225	31,131
7	37,541	31,131
8	32,753	27,512
9	32,412	27,162
10	32,034	26,779
11	32,620	26,315
12	31,159	25,819
13	30,652	25,210
14	30,086	24,598
15	29,461	23,870
Present Value of Annual Net Cash flow	304,097	249,658

[a] The cash flow after taxes was calculated by subtracting fixed annual costs of irrigation equipment, capital, labor, land, and property taxes from the returns to the fixed cost, labor, and management calculated in the annual mathematical programming model. A fixed farm machinery loan payment of $23,040, a land rental cost of $42,240 and a hired labor cost of $8,000 were assessed to each system. An annual cost for irrigation systems based on loan repayment, repairs, property tax, and insurance was charged at a level consistent with the acreage of irrigation selected for a particular management system.

is presented in Table 4.8. The present value of the annual cash flow is highest for the combination of 50 percent irrigated and 50 percent dryland corn production. The discounted present value of $282,887 is greater than either $276,900 or $273,606, yielded by the other combinations presented in Table 4.8 and it is greater than the medium cost 100 percent irrigated corn system presented in Table 4.7.

Certain factors influence the economic superiority of the different scales of irrigation systems on the farm. For example, the net present value is influenced by the size of the capital investment through the depreciation schedule, investment credit, and loss carryover which shield the first seven years of cash flow from taxes.

The most important factors influencing the optimum scale of irrigation is the increase in revenue at a decreasing rate as irrigated acreage increases while the cost rises at a constant rate. Revenue does not increase at a constant rate with scale because constant percentage penalties for lack of timeliness in production activities result in higher per acre penalties for irrigated corn than occur for dryland corn production. It is clear that high yielding crops incur a greater per bushel yield decrease as a result of late harvest or planting, than occurs for the same number of days delay for a low yielding crop. When dealing with a typical farm situation where crops cannot all be planted or harvested in the most optimum time periods due to labor and machinery constraints, this phenomena has an important impact upon the revenue of the farm firm. If these yield-time relationships did not exist and a constant linear increase in yield occurred as scale increased, the 100 percent irrigated system would always be more profitable than the smaller scales of irrigation systems.

Table 4.8. Economic Returns to Irrigated Corn Production: Surface Water Impoundments.[a/]

System Description	Dryland and Irrigated Corn Medium Cost	Dryland and Irrigated Corn Medium Cost	Dryland and Irrigated Corn Medium Cost
Acreage Allocations	464 A. Irrigated Corn 160 A. Dryland Corn 16 A. Lanes	309 A. Irrigated Corn 320 A. Dryland Corn 11 A. Lanes	154 A. Irrigated Corn 480 A. Dryland Corn 6 A. Lanes
Revenue	$186,752	$174,282	$160,407
Allocated Variable Cost	50,700	47,508	43,630
Return to Fixed Cost Labor & Management	136,052	126,774	116,777
	---------Annual Net Cash Flow after Taxes---------		
Year 1	34,408	35,759	34,630
2	34,408	35,759	34,630
3	34,408	35,759	34,630
4	34,408	35,759	31,624
5	34,408	35,759	31,473
6	34,408	34,503	31,165
7	34,408	31,263	31,011
8	30,257	30,943	30,871
9	29,960	30,623	30,731
10	29,640	30,303	30,591
11	29,288	29,946	30,451
12	28,919	29,568	30,294
13	28,469	29,190	30,118
14	27,983	28,780	29,942
15	27,459	28,342	29,766
Present Value of Annual Net Cash Flow	276,900	282,887	273,606

a/ The cash flow after taxes was calculated by subtracting fixed annual costs of irrigation equipment, capital, labor, land, and property taxes from the returns to the fixed cost, labor, and management calculated in the annual mathematical programming model. A fixed farm machinery loan payment of $23,040, a land rental cost of $42,240 and a hired labor cost of $8,000 were assessed to each system. An annual cost for irrigation systems based on loan repayment, repairs, property tax, and insurance was charged at a level consistent with the acreage of irrigation selected for a particular management system.

These results indicate that a farmer who considers water impoundment for irrigation needs to (1) explore techniques to reduce the cost of impoundment such as construction with farm equipment, (2) examine carefully the location of the potential impoundment area in relation to the field to be irrigated so pumping costs can be minimized, and (3) consider the rainfall pattern and watershed size which will determine the rate and timing of reservoir recharge. Only when these aspects are carefully analyzed can the decision of whether to add a water impoundment irrigation system to a farm be accurately determined.

If the only storage alternative for a farmer is a pond where a 1:1 ratio of excavated soil to water impoundment would be required rather than a 1:3 ratio assumed above, the irrigation option would not be economically competitive. At a cost of one dollar a cubic yard for earth movement, a farm irrigation system with 619 irrigated acres would require an $188,000 capital investment in water storage alone. The additional revenue gained from irrigation is insufficient to offset the higher annual cost associated with this level of water storage investment. Dryland corn production would be preferable in this case.

Sensitivity to Yield and Discount Rate

Further analysis was conducted of the sensitivity of the results of the research to increases in the rate of discount or decreases in the corn yield response to irrigation. The results of this analysis are presented in Table 4.9. The comparison in this table is between the production of dryland corn under variable weather conditions and the production of irrigated corn produced with a medium cost impounded water system.

Table 4.9. Present Value of the Annual Cash Flow for Alternative Discount Rates and Irrigated Corn Yields.

Production System and Yield	Discount Rate		
	8%	12%	16%
Dryland Corn with Variable Weather[a/] 86 bu./A. Ave. Yield[b/]	$157,645	$124,433	$100,819
Irrigated Corn[c/] 131 bu./A. Ave. Yield[b/]	249,658	155,117	86,394
Irrigated Corn[c/] 121 bu./A. Ave. Yield[b/]	141,247	72,313	
Irrigated Corn[c/] 111 bu./A. Ave. Yield[b/]	44,848		

a/ The dryland system is calculated for each level of discount by computing the average of the PVACFAT for the late dry years and early dry years (Table 4.5) based on a 20 percent probability (1 year in 5) that dry weather would reduce yield by 48 percent (See Table 4.3).

b/ Yield data from which these averages are calculated are presented in Tables 4.2 and 4.4. The dryland system involves 640 acres of dryland corn production and the irrigated system has 619 acres of irrigated corn with water supplied from a medium cost impounded water source.

c/ The irrigated corn system is the 619 acres irrigated system with medium cost impounded surface water (See Table 4.7).

Irrigated corn production is more profitable than dryland production when the average yield is 131 bushels per acre and the discount rate is either 8 percent or 12 percent. However, when the discount rate rises to 16 percent, dryland corn production yields a higher present value of the annual cash flow than does irrigated corn. When the average yield increase for irrigation is lowered to 35 bushels/acre (121 bushels/acre for irrigated corn) the irrigation system is always less profitable than the dryland system at any of the three discount levels considered.

These results clearly indicate the importance of an average yield increase of at least 40 bushels per acre per year or a discount rate of no more than 14 percent if irrigation systems are to be expected to provide greater returns than dryland corn production.

CHAPTER V

SUMMARY AND CONCLUSIONS

This comparison of irrigated and dryland production on soils with restricted rooting zones indicates there is an opportunity for economically successful employment of irrigation systems. The present value of the annual cash flow for selected production systems is presented in Table 5.1. Comparing these present values indicates when irrigation potential is more profitable than dryland production and vice versa.

The emphasis in this summary is on comparison of dryland and irrigated systems rather than emphasizing the level of profitability of either system. The particular level of profitability shown is influenced greatly by the levels of fixed cost for land, farm machinery and labor that are the identical in either irrigated or dryland systems. Changes in levels of the fixed cost would significantly influence the level of profitability of any of these systems, but only slightly influence the relative comparison of which system is most profitable.

In the rare situation where shallow wells can be used to provide water for irrigation on soils with restricted rooting zones, irrigation yields a higher net present value than does dryland production. Even when the highest cost well assumption is compared to the most favorable dryland conditions, the irrigated system generates more income after taxes over the 15 year life of the irrigation system. The problem with this comparison is that ground water supplies in claypan regions are extremely limited. Water is usually not available at shallow depths or at a great enough rate of flow to provide this profitable investment opportunity to more than a few of the many farm operators in these regions.

Table 5.1. The Economic Potential for Irrigating Claypan Soils.[a]

Production System	Present Value of the Annual Cash Flow after Taxes
Dryland Corn[b]	$157,645
Corn Irrigated from Shallow Wells[c]	315,293
Corn Irrigated from Ponds[d]	249,658
Corn Irrigated from Ponds--Low Yield[e]	141,247
Corn Irrigated from Ponds--High Discount Rate[f]	86,394

[a] This is the present value for the 15 years considered appropriate for assessment of the irrigation investment.

[b] This is the dryland corn system at 8 percent discount rate with 86 bushels per acre average annual yield presented in Table 4.3.

[c] This system is the medium cost shallow well system at 8 percent discount rate with an 131 bushel per acre average annual yield described in Table 4.4.

[d] This system is the medium cost system with water from ponds with an 8 percent discount rate and a 131 bushel per acre average yield from Table 4.7.

[e] This irrigated system is the medium cost pond water system with an average yield of 121 bushels per acre and an 8 percent discount rate presented in Table 4.9.

[f] This system is a medium cost pond water source system with a discount rate of 16 percent and a yield of 121 bushels per acre described in Table 4.9.

Since the topography in claypan areas involves steep slopes and high rates of rainfall runoff, impoundment of water through the construction of small earthen dams is a more likely source of irrigation water than wells. The results of this analysis indicate in most situations this option is more profitable than dryland production. In Table 5.1 it can be noted that irrigated corn with water from ponds has a $92,013 greater net present value over 15 years than dryland production. Pond construction costs are highly variable depending on the topography at a particular site. When poor site topography results in a low ratio of water impounded to earth moved in construction, the irrigation of corn from pond water is less profitable than dryland production. However, it appears that pond water supply irrigation systems provide profitable investment opportunities for some farmers in the claypan region.

When the expected yield from irrigated corn is reduced to 121 bushels per acre from the 131 bushels used in the analysis (a 35 bushel per acre yield advantage over dryland corn), dryland production is more profitable than irrigated production. If the rate of discount is increased to 12 percent and then 16 percent from the 8 percent used in the analysis, the irrigated system is still more profitable than dryland at 12 percent, but dryland is more profitable at a 16 percent rate of discount.

Although it is difficult to generalize the results of this study because individual farm situations are highly variable, it appears that irrigation of corn on soils with restricted rooting zones is more profitable than dryland production in a number of different situations. A particular farmer would have to examine carefully the cost of providing irrigation water, the cost of borrowed capital, the yield response expected for irrigation, and the price of corn in order to evaluate the profitability of irrigation for his situation.

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APPENDIX A

Calculation of After Tax Annual Net Cash Flow

309 A Irrigated Corn, 320 A Dryland Corn
Medium Cost - Surface Water Impoundment
Irrigation Systems
(From Table 4.8 in Text)

Item	
Irrigation Investment Costs	
Pond	$47,000
Buried Pipe	13,200
Distribution System	31,000
Pumps and Motor	30,400
Total Irrigation Investment	$121,600
Annual Cash Flow	
Revenue	$174,282
Variable Cost	47,508
Machinery Loan Payment	23,040
Hired Labor	8,000
Land Rent	42,240
Irrigation Equipment Loan Payment	14,206
Irrigation Equipment Repairs, Tax, & Ins.	3,529
Net Annual Cash Flow	35,759

Tax Computation

Year	Depreciation [a]	Interest Paid [b]	Taxable Income [c]	Tax [d]	Investment Credit [e]	Cash Flow After Taxes
1	22,874	9,782	-42,033	0		35,759
2	6,894	9,369	7,200	0		35,759
3	5,976	8,982	7,200	0		35,759
4	5,178	8,564	11,314	694	694	35,759
5	4,488	8,113	24,969	3,857	3,857	35,759
6	3,890	7,626	26,054	4,165	2,909	34,503
7	3,335	7,099	27,135	4,496		31,263
8	2,922	6,531	28,117	4,816		30,943
9	2,532	5,917	29,121	5,136		30,623
10	2,194	5,254	30,122	5,456		30,303
11	1,902	4,537	31,131	5,813		29,946
12	1,638	3,764	32,168	6,191		29,568
13	1,420	2,928	33,222	6,569		29,190
14	1,232	2,026	34,312	6,969		28,790
15	1,066	1,052	35,452	7,417		28,342

a/ This column involves a declining balance depreciation system with 20% additional depreciation taken in the first year.

b/ Interest payments are made on the loans for farm machinery and the irrigation systems. Loan interest rates in this case are 8% per annum.

c/ The tax loss from year one is carried over to reduce taxes in years 2 through six.

d/ Tax computation are based on a family of four persons taking standard deductions.

e/ Investment credit is carried over and used in years 4, 5, and 6 after tax loss carryover from year one has been fully utilized.